

Search for Transient Sources on a Monthly Time Scale

Toby Burnett

University of Washington

Collaborators:

Elisabetta Cavazzuti, Gino Tosti, and
on behalf of the Fermi-LAT Collaboration

Point source detection: time scales and techniques

- Long -- catalog
 - 1FGL (11 months) 2FGL (2 years), 3FGL (4 years), ...
 - Wavelet (PGWAVE), TS map (full likelihood on 3.2M points)
- Short, flare-oriented
 - FAVA sky-map differencing (weekly)
 - In 48 months, found 611 not in the 3FGL catalog (13/month)
 - ASP flare detection with PGWAVE (8 hours)
- This work
 - Use same methods as for catalog, with model including preliminary 6-year source list
 - Identifies sources that are detected in a single month
 - Potential flares
 - First time this has been tried!

The xFGL Catalogs

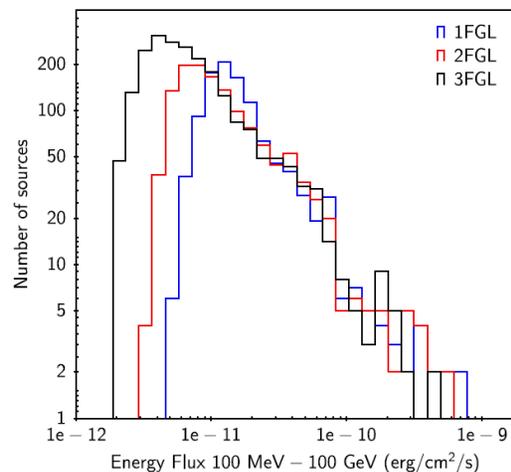
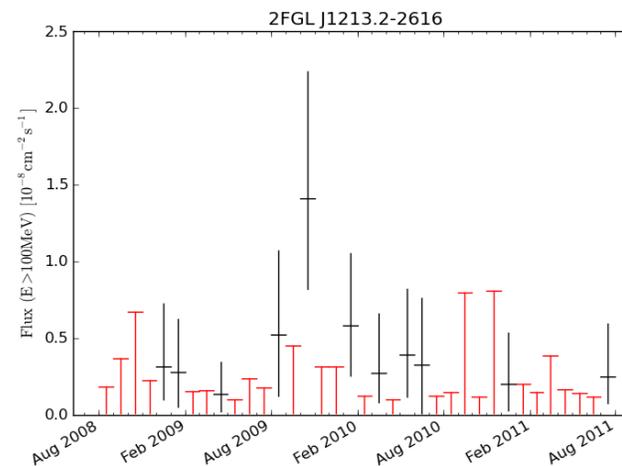


Fig. 18.— Distributions of the energy flux for 1FGL (blue line), 2FGL (red line), and 3FGL (black line) sources at high Galactic latitude ($|b| > 10^\circ$).

Name	Duration	Sources
1FGL	11 m	1451
2FGL	2 yr	1873
3FGL	4 yr	3033

From the 3FGL paper, showing how sensitivity increases with observing time ... but this is in principle only true for \sim constant sources

Light curve for a 2FGL source that was not included in 3FGL

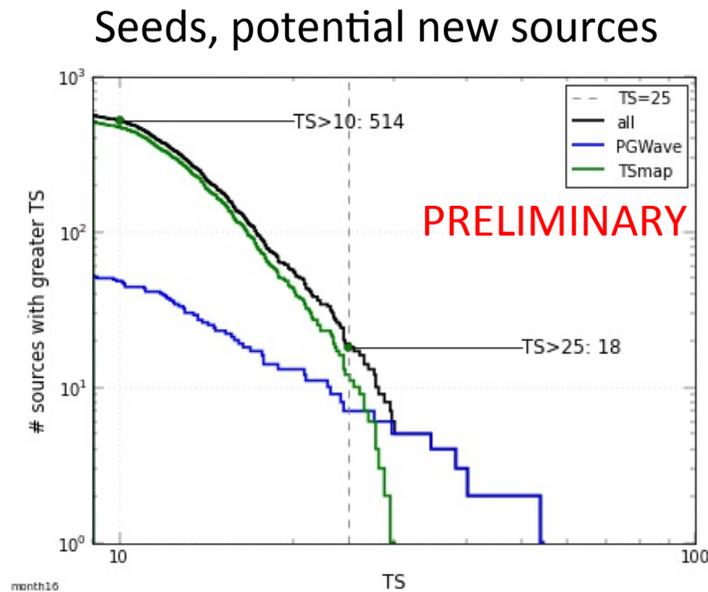


Data and analysis

- Data: Pass 8, first 6 years
- Analysis
 - Full 6 years
 - Same as performed for 3FGL and documented in the paper, except:
 - Combine limb with “isotropic”, measure normalization for each energy band and ROI
 - TS map technique detection supplemented by PGWAVE: added 37 TS>10 (7 with TS>25)
 - Sources found: 6568 with TS>10, 4515 with TS>25
 - For each of 72 individual months
 1. Initial model: all 6-year sources, vary normalization only; same diffuse
 - Keep those with TS>10: ~1200 per month
 2. Initial source finding with PGWAVE: add seeds and iterate
 3. Final source detection using TS map, Sun position masked, iterate
 4. Make associations of the new sources, especially with respect to the BZCAT catalog

Monthly analysis

Cumulative TS for a single month, showing sources added to the model, first by the PGWave wavelet step, then the TSmap stage

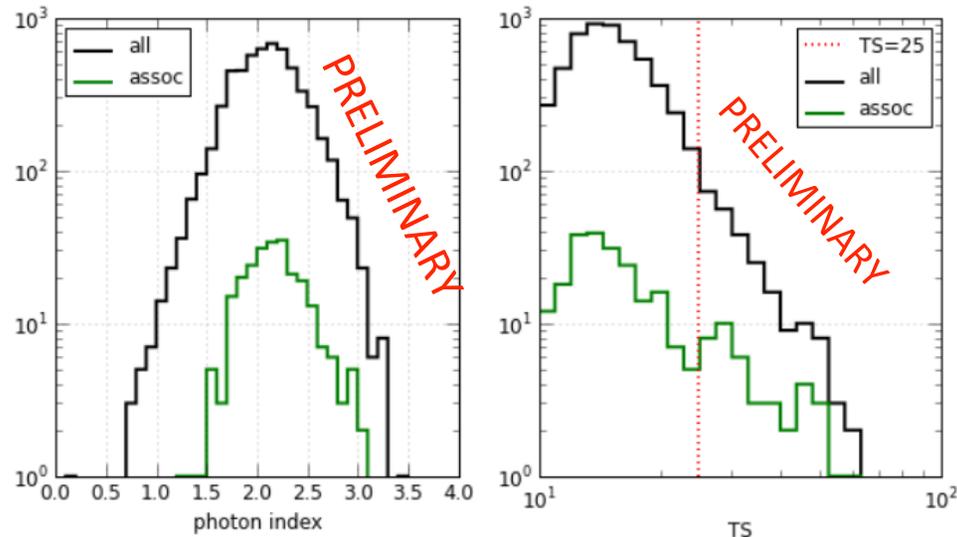


This is **in addition** to the ~1200 sources from the 6-year model

Properties of the combined set

Showing the subset with any association

Select all clearly not
related to 6-year sources:
27192 (378/mo)
682 have $TS > 25$ (9/mo)

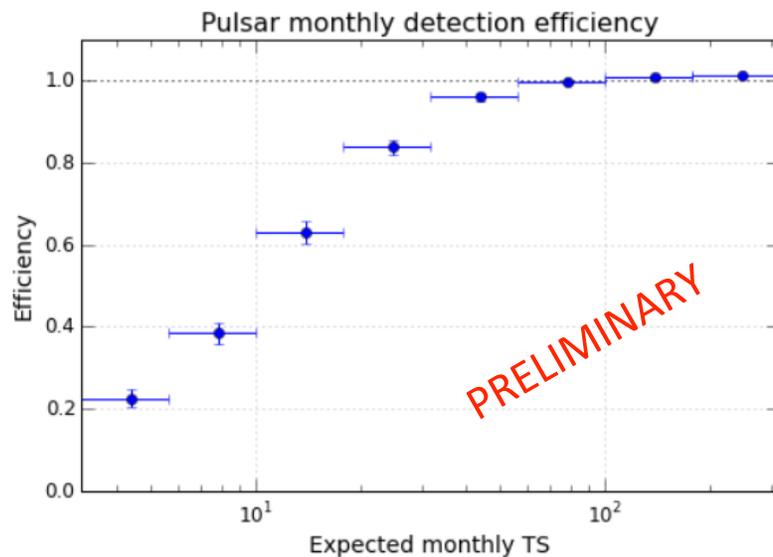


About the Test Statistic (TS):

- Final catalog analysis only keeps $TS > 25$.
- There seem to be many associations down to $TS = 10$; BUT need to worry about spurious, random correlations of photons

Pulsars: use to calibrate

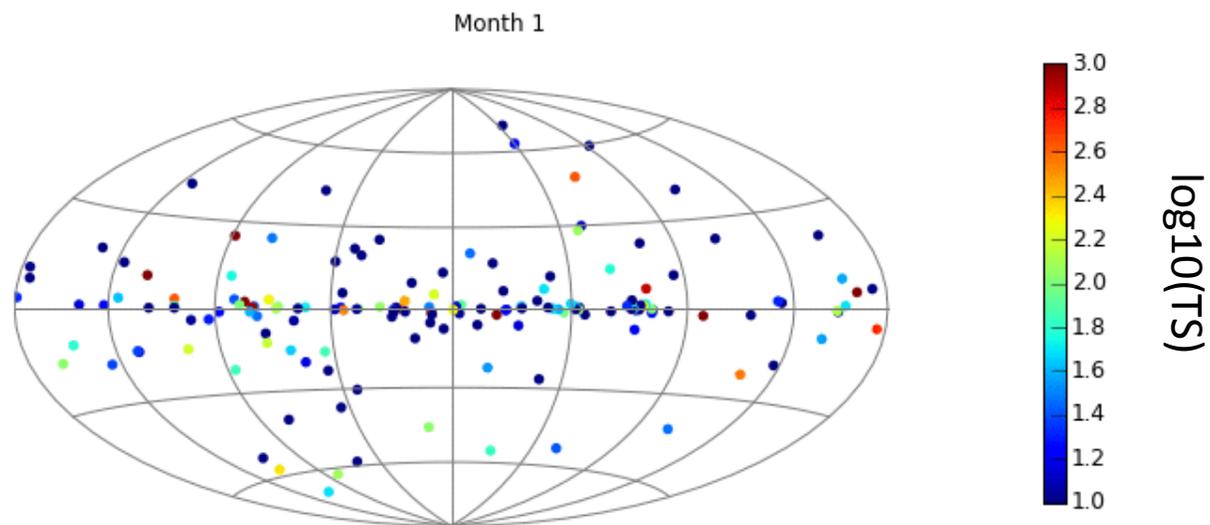
Examine the monthly fits to the 176 DC-detected pulsars in the 6-year set.



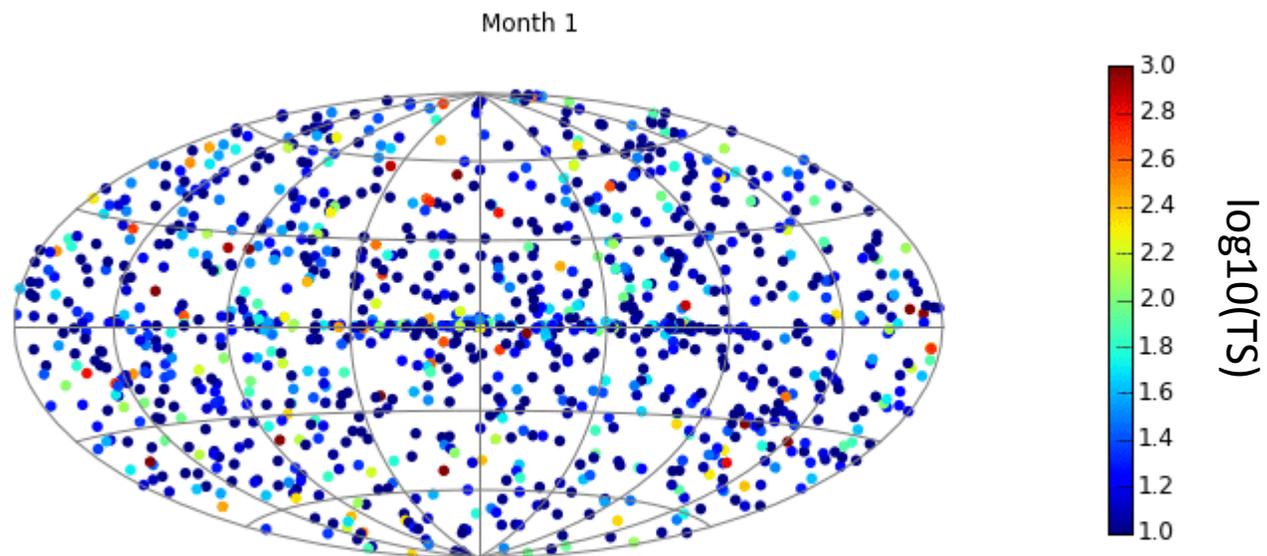
Monthly pulsar detection efficiency, as a function of the expected TS (1/72 of 6-year TS)

→ Detect about half of sources that would have TS=10

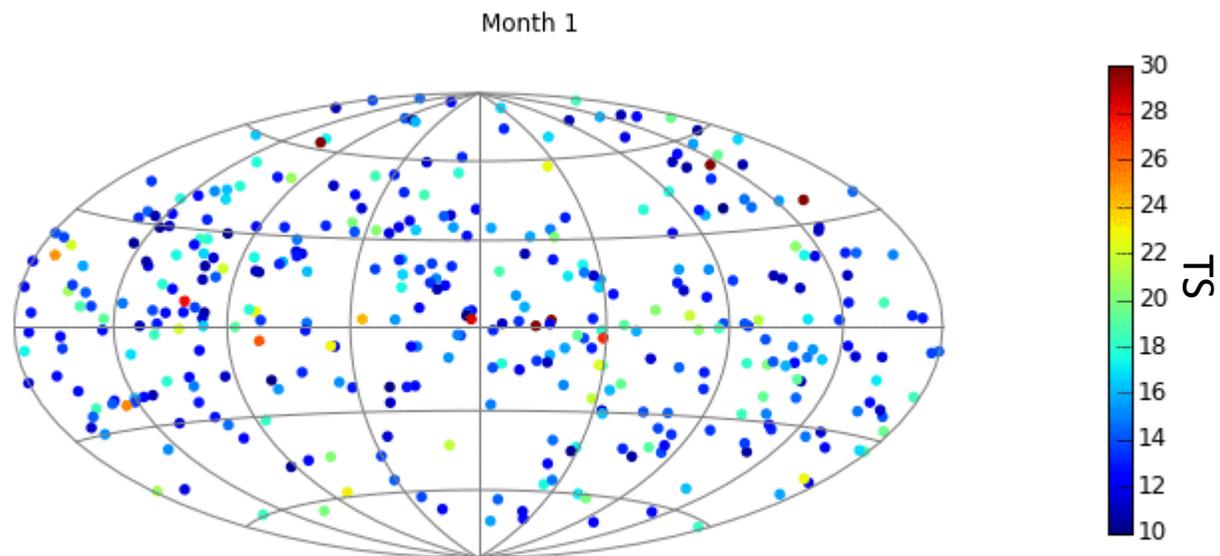
Animation: LAT pulsars



Animation: All 6-year sources

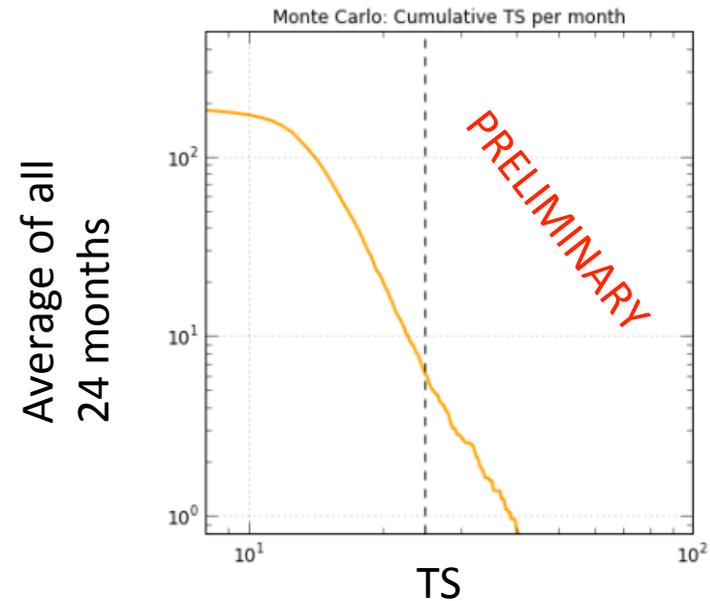


Animation: monthly detections



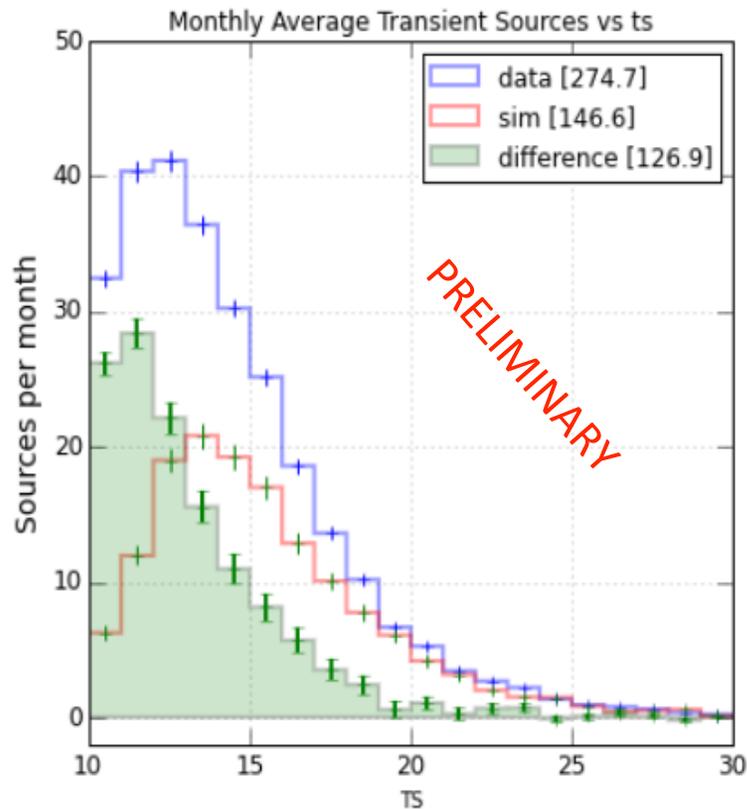
Simulation: how many are spurious?

- Data set: 24 individual months
 - Sources from 3FGL, ideal diffuse
- Analysis
 - Same as for data, but use 3FGL model
 - Cumulative TS plot:



Predicts ~200 per month!

Comparison with simulation



Require:

- high latitude, $|b| > 10$,
- $> 0.5^\circ$ from long-term source

Net: $274 \pm 2 - 147 \pm 2 = \mathbf{127 \pm 3}$ (statistical errors)
possible new sources per month with $TS > 10$

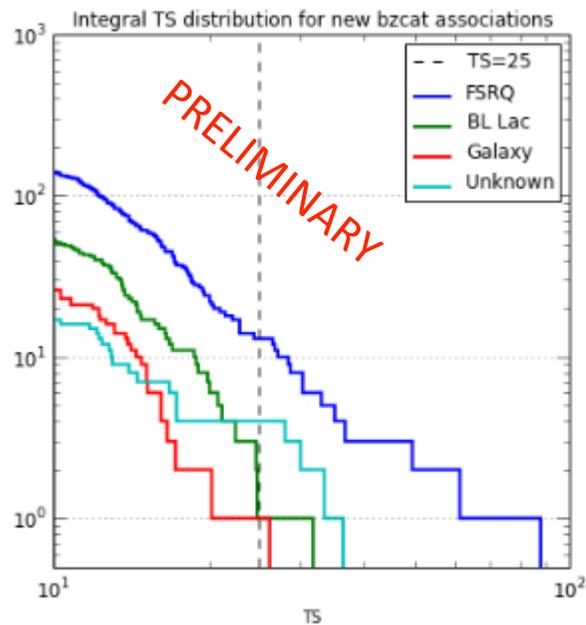
BZCAT associations

- Use to check for an expected contribution
 - Based on Bayesian association analysis
- BZCAT: 5th edition: [ARACNE editrice S.r.l., ISBN 978-88-548-4309-8 \(2014\)](#)
 - Known blazars, with radio and optical analysis
 - Based on multi-frequency surveys and on an extensive review of the literature.
 - Classified as BL Lacertae objects, as flat spectrum radio quasars (FSRQ) or as blazars of uncertain/transitional type.
 - Each object is identified by a root name, coded as BZB, BZQ and BZU for these three subclasses respectively, and by its coordinates.

spectral type	Number	Fraction (%)
BL Lac	1151	32.3
FSRQ	1909	53.6
radio galaxy	274	7.7
unknown	227	6.4

BZCAT associations with monthly data

291 detected: 262 in only a single month



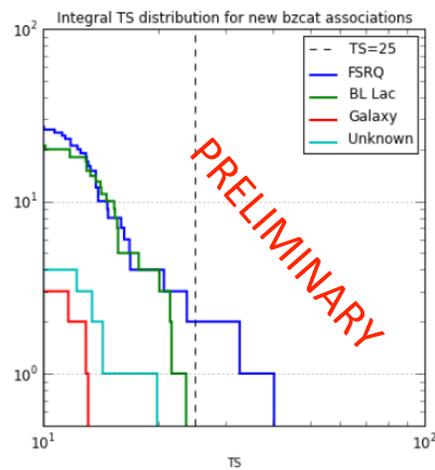
AGN type counts for monthly data

	TS>10	TS>25
FSRQ	186	13
BL Lac	67	1
unknown	22	4
Radio galaxy	32	1

BZCAT simulation comparison

Compare the integral TS distributions

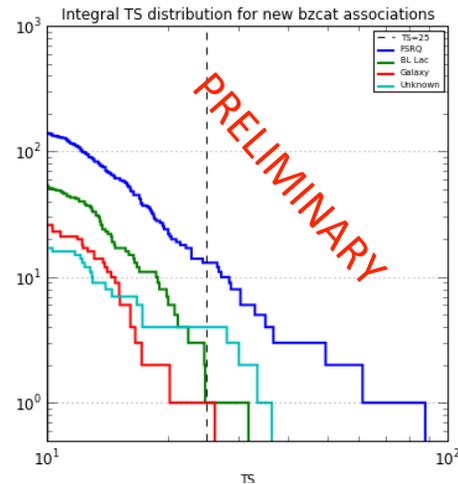
Sim (24months)



AGN type counts for monthly data

	TS>10	TS>25
FSRQ	26	2
BL Lac	22	1
unknown	4	0
Radio galaxy	3	0
Total	55	3

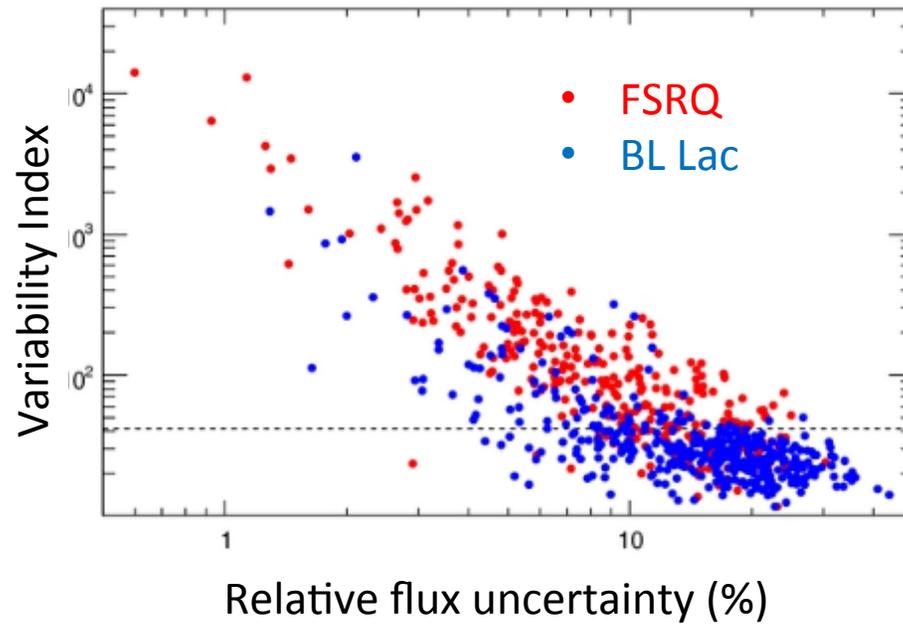
Data (72 months)



AGN type counts for monthly data

	TS>10	TS>25
FSRQ	140	13
BL Lac	52	1
unknown	17	4
Radio galaxy	26	1
Total	235	19

FSRQ blazars are variable

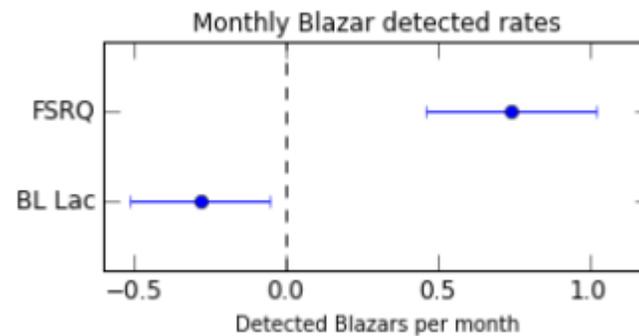


From the Fermi 2LAC paper:
FSRQ are much more variable.

Compare FSRQ and BL Lac rates

Monthly rates of associated blazars, by type for TS>10

Type	Data	Sim	Difference
FSRQ	1.94 ± 0.16	1.21 ± 0.22	0.74 ± 0.28
BL Lac	0.72 ± 0.10	1.00 ± 0.20	-0.28 ± 0.23



- FSRQ 2.6σ significance
- BL Lac consistent with zero

Conclusion

A search for sources detectable only on monthly time scales, in 72 months, has tentatively found significant numbers of weak ($TS > 10$) sources, $>100/\text{month}$

- Large spurious contamination
- Some are associated with FSRQ blazars associated for the first time, consistent with expectations based on variability